Advanced Laser Proximity Fuzing

Presented at the

'First Annual International

Missiles & Rockets Symposium'

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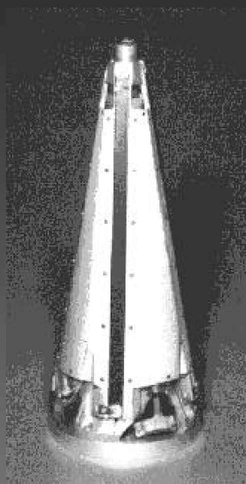
by

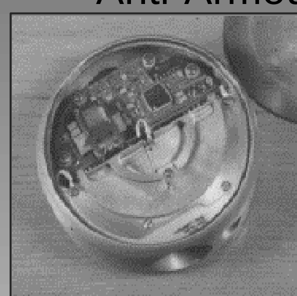
Gary Buzzard



Air Target Radar Proximity Fuzing

Air Target Laser Proximity Fuzing

Anti-Armour Proximity Fuzing



Fly Over Shoot Down

Direct Attack

THOMSON-THORN MISSILE ELECTRONICS

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Advanced Laser Proximity Fuzing

TME Pedigree

- Europe's leading Fuzing and Missile Electronics Supplier
  - Hard Target Fuzing
    - MFBF, MAFIS, HTSF, MEHTF
  - Anti-Armour Fuzing/Target Detection Devices
    - FITOW, TRIGAT, TOW-2B
  - *Air Target Fuzing /Target Detection Devices*
    - *Rapier, ASRAAM, AMRAAM*
  - Smart Artillery Munitions
    - STAR, LCGM
  - Airborne Seekers

- US Activities
  - AMRAAM TDD Second Source Supplier
  - Core Team Member of US/UK PIOS Programme
  - Sole Source Supplier of TOW-2B TDD
  - USAF HTSF and MEHTF Hard Target Fuzes (with Alliant Techsystems)

Advanced Laser Proximity Fuzing

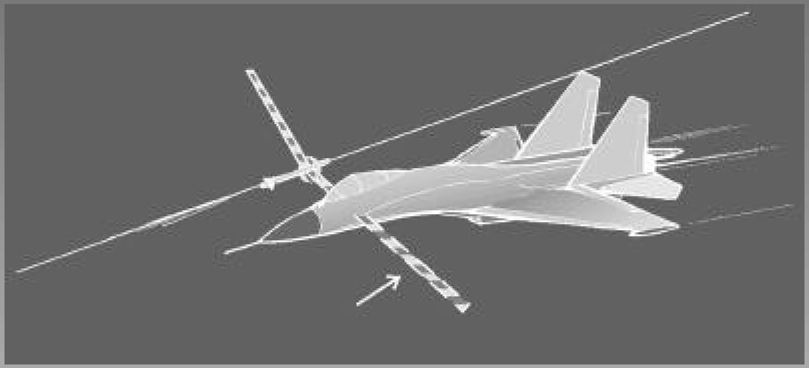
The Role of the Proximity Fuze

- To issue a trigger signal commanding initiation of the lethal mechanism at a point during an engagement designed to provide optimum lethality.
- To be resistant to false triggering in the presence of naturally occurring clutter, man made clutter and countermeasures.

Proximity Fuze [UK] = Target Detection Device [US]

ANTI-AIR TARGET MISSILES

- Axi-symmetric fragmenting warheads
- Conical or multiple sector beam configurations
- Radar, laser and Passive IR technologies
- First point ‘seen’ + time delay to trigger
- Closest point of approach triggering



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Existing TME Laser Fuze Products

- Semiconductor laser sources
  - Near IR Pulsed or CW
  - Compact and mature
- Silicon detectors - uncooled, low cost
- Plastic or glass optics
- Well defined beams
  - Conical, sectored or spoked
- Time of flight down-beam range
  - Closest point of approach triggering
- Highly effective in current applications
- Maximum operating range constrained by:
  - Need to prevent false alarm in cloud
  - Signal to noise

Rapier Proximity Fuze

ASRAAM Proximity Fuze

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Increasing sensitivity and coverage

- Future requirements likely to necessitate increased sensitivity and coverage
  - Manoeuvring targets ⇨ greater miss distances
  - Stealthier targets ⇨ lower reflectivity
- Signal to noise of existing sensors constrained by semiconductor laser diode limitations
  - Mature technology
  - Higher power devices unlikely to evolve
- Laser diode pumped Nd:YAG ‘Microlaser’ devices offer a attractive alternative
  - Significant potential sensitivity improvement
  - Compact and robust devices available
  - Compatible with volume manufacture
  - Several commercial sources

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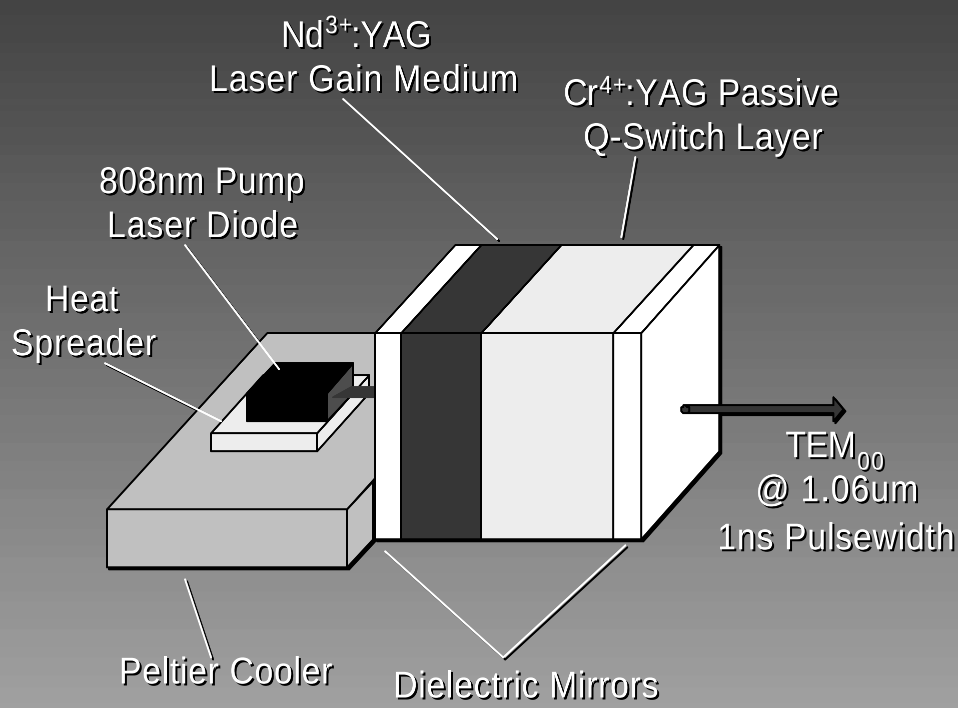
Microlaser Construction

- Pump source
  - Semiconductor laser
  - CW
  - ~1Watt mean power
  - Peltier cooled
- Nd:YAG gain medium
- Saturable absorber
  - Cr^{4+}:YAG
  - Pulsed output



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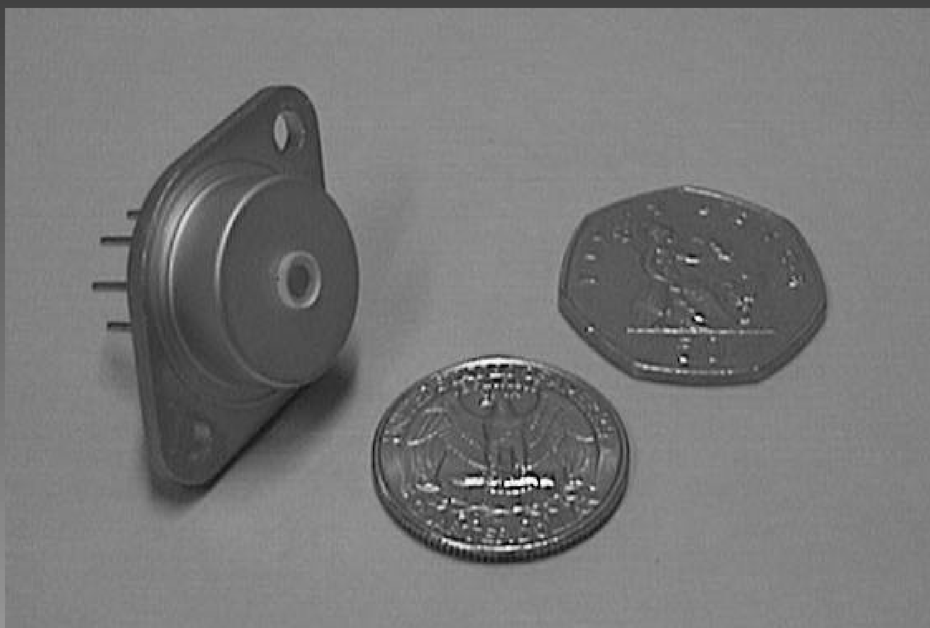
Microlaser Packaging



- Integrated
  - Pump laser
  - Peltier cooler
  - Nd:YAG laser
  - Saturable absorber
  - Blocking filter
- TO3 package
  - Industry standard
  - Compact
  - Missile compatible

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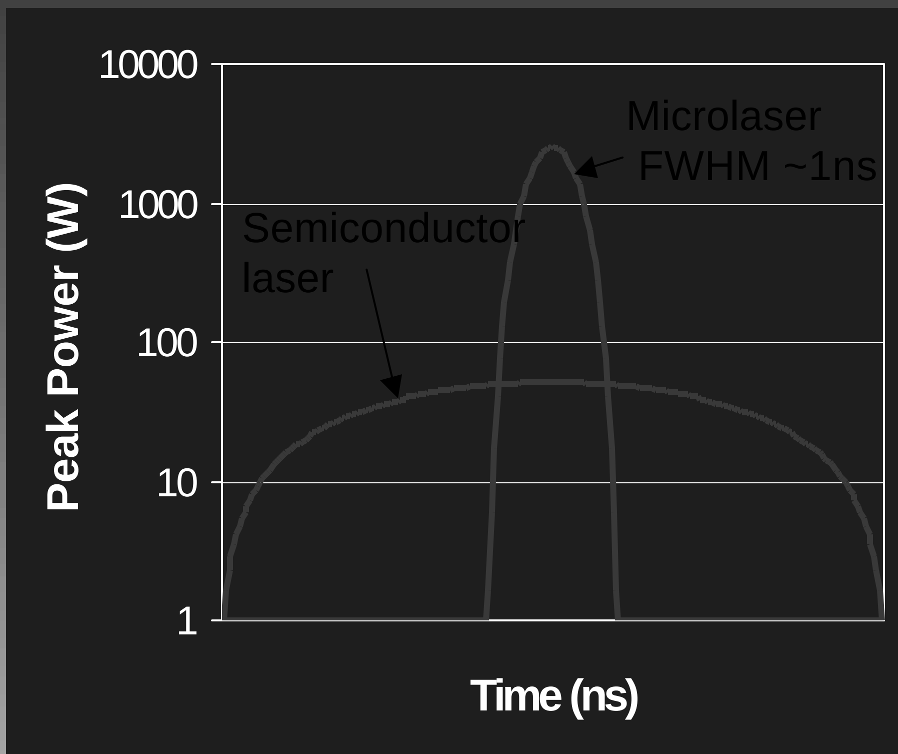
Microlaser Versus Semiconductor - Pulse Characteristics



- Microlaser pulse much narrower than semiconductor laser
  - Enhanced range resolution
  - Lower aerosol backscatter
- Microlaser peak power much higher
  - ~ 3kW (~ 50 X higher)
  - Pulse energy ~ 3❍J
- Pulse repetition rates similar
  - Microlaser ~ 15kHz

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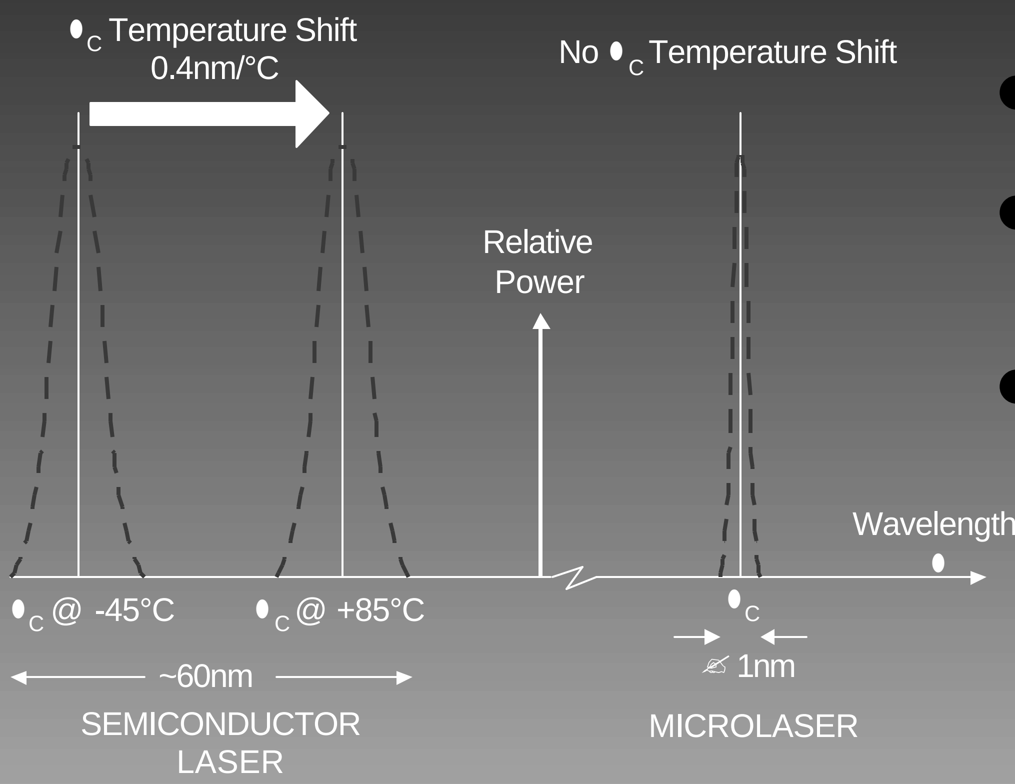
Microlaser Versus Semiconductor - Spectral Characteristics



- Microlaser linewidth much narrower than semiconductor
- Semiconductor centre wavelength varies significantly with temperature
- Microlaser allows use of a narrower band receiver
  - Reduced background at detector
  - Reduced receiver noise

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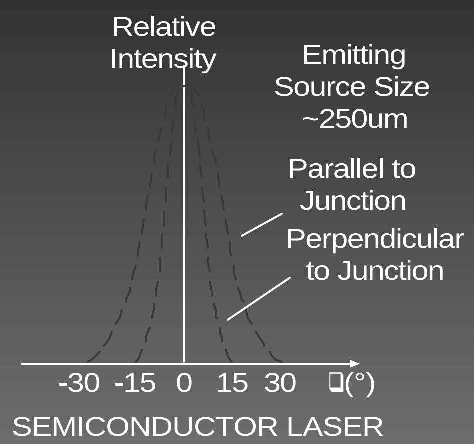
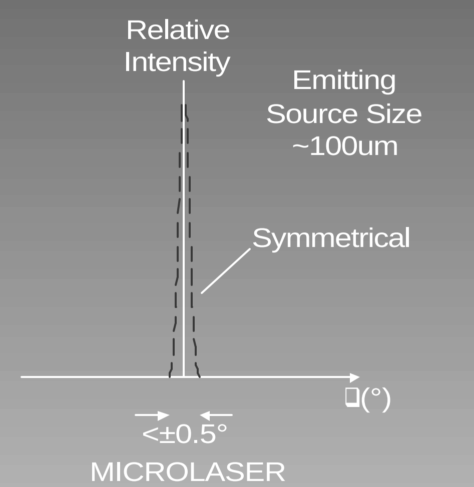
Microlaser Versus Semiconductor - Beam Divergence





- Semiconductor laser output
  - Large emitting area (facet ~300 µm)
  - Highly divergent (up to ±30°)
  - Asymmetric
  - Requires ~F1 collimation
  - Resulting beam width large ~10mm
- Microlaser output
  - Small emitting area (<100 µm)
  - Low divergence (<1°)
  - Further collimation unnecessary
  - Very narrow beam
  - Allows compact beam forming and window optics
  - Allows high forward look angles

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Pulse Digitising Microlaser Laser Fuze Demonstrator

- UK Pathfinder programme
  - Jointly funded with MoD DERA (Defence Evaluation & Research Agency)
  - 2 year duration (1998 to 2000)
- Demonstration of the potential application of new technologies
  - Microlaser devices
    - Improved coverage and resolution
  - Received signal digitisation and signal processing
    - Enhanced clutter discrimination
- Design and build of a 2 sector experimental fuze
  - Scanned pencil beam Microlaser transceiver
  - Fixed fan beam Microlaser transceiver
- Detailed design completed late 1999
- Procurement completed and hardware assembly planned to start March 2000

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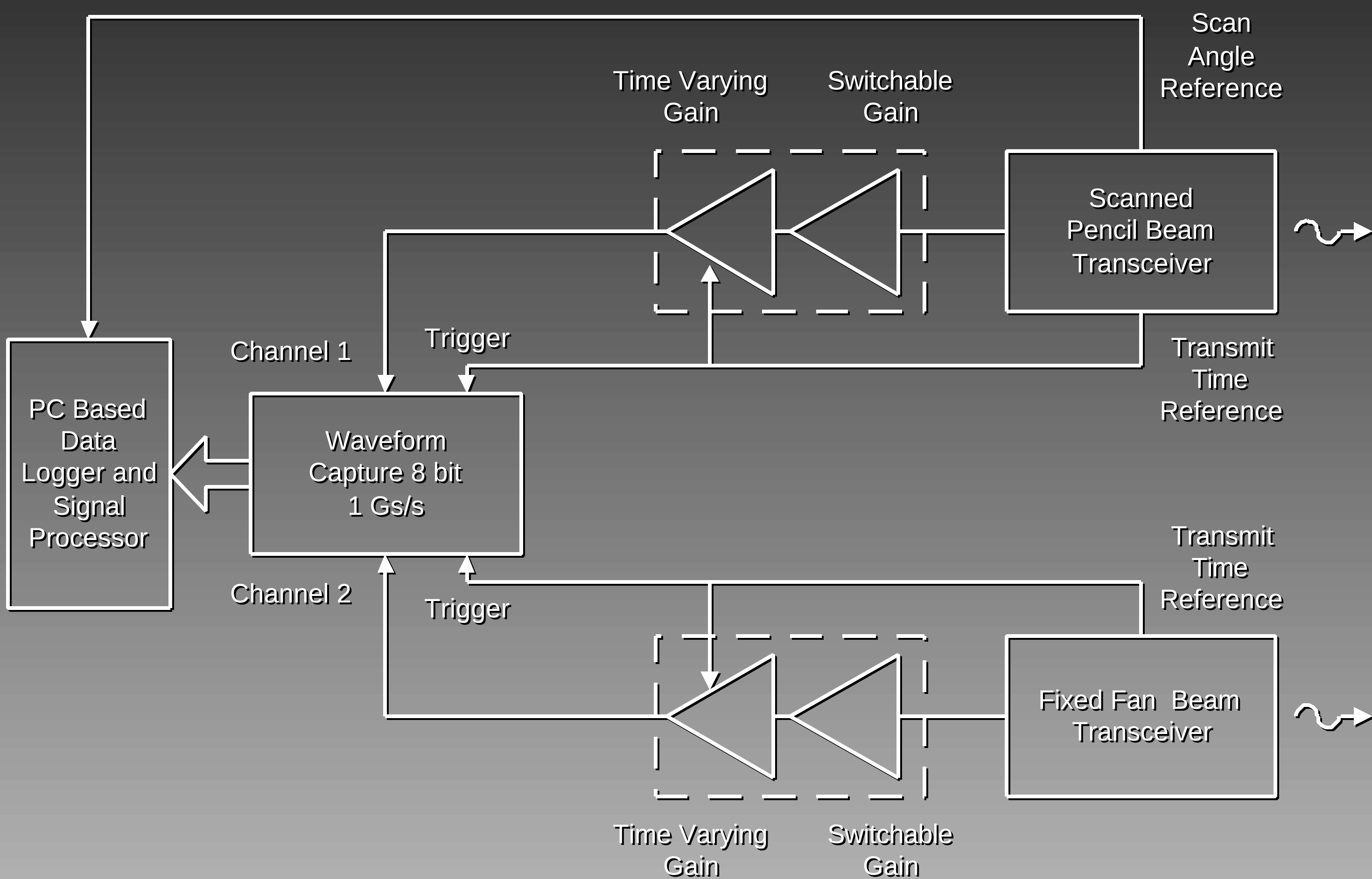
Demonstrator Functional Block Diagram



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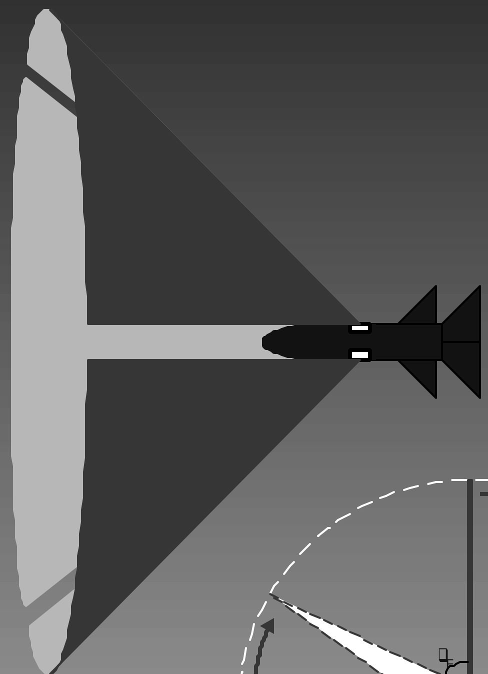
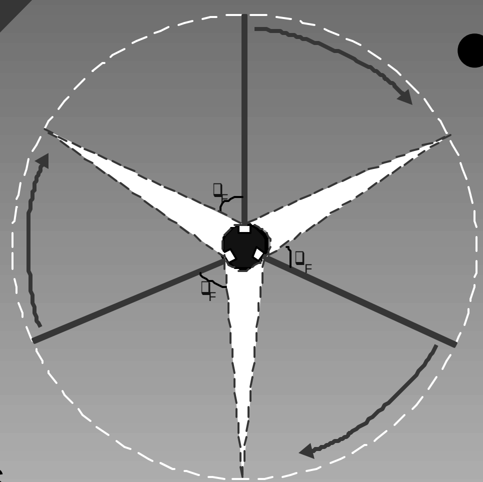
Scanned Pencil Beam Transceiver Configuration





Coverage
provided by
3 transceivers

- Transmitter
  - Pulsed Microlaser
  - Scanning mechanism
  - 45° forward looking conical locus
  - 120° roll coverage (swept)
  - 4kHz maximum scan repetition rate
- Receiver
  - Complementary scanning mechanism
  - Narrow band filter
  - Focusing lens
  - Avalanche Silicon APD
  - Transimpedance pre-amplifier

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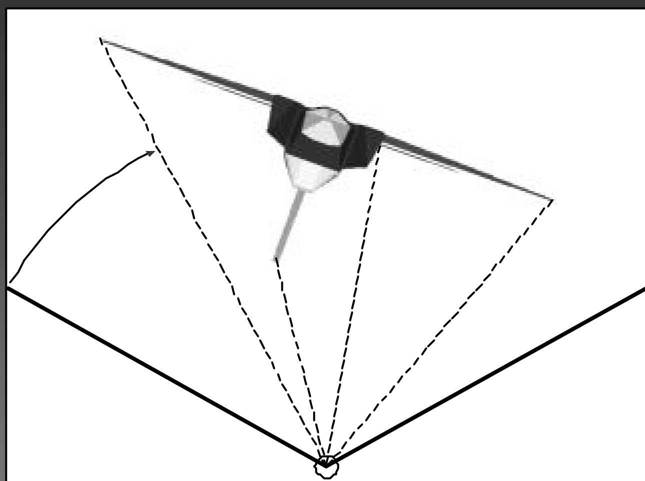
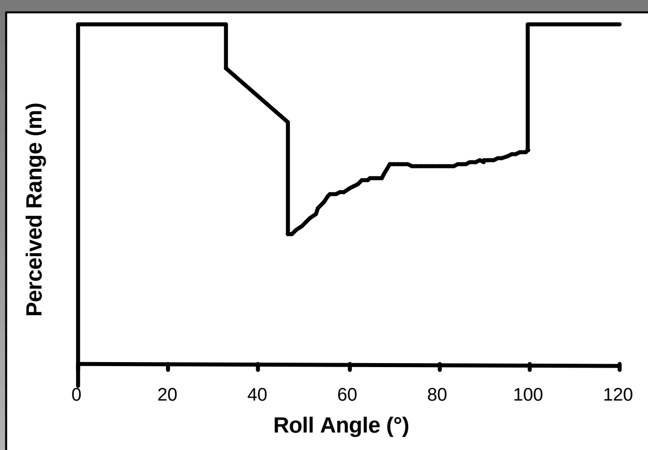
Scanned Pencil Beam Sensor - Predicted Performance





- 2-D range profile of target surface
  - Conical cross-section
  - Repeated at scan rate (4kHz)
- Excellent detection range
- Range resolution ~0.25m
- Roll angle resolution dependent on laser repetition rate (100kHz required for ~5°)
- 3-D surface profile of target
  - Built up from consecutive scans
  - Available up to trigger point
- Potential target feature extraction
  - Enhanced trigger point processing
- Good clutter (cloud) discrimination
  - Inherent for pencil beam

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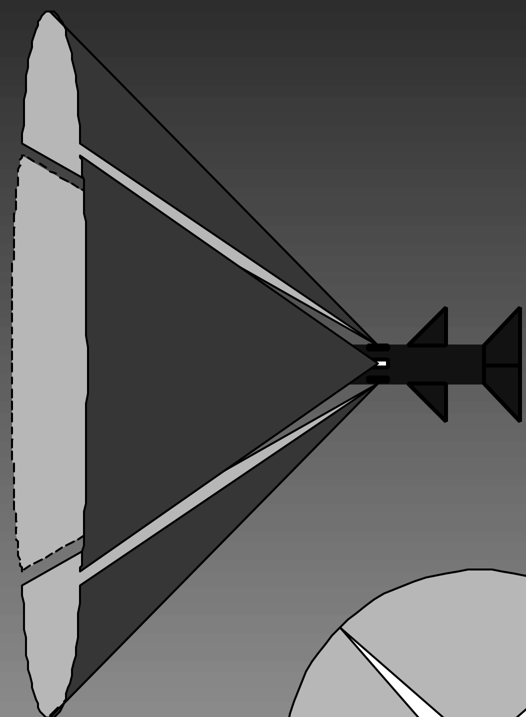
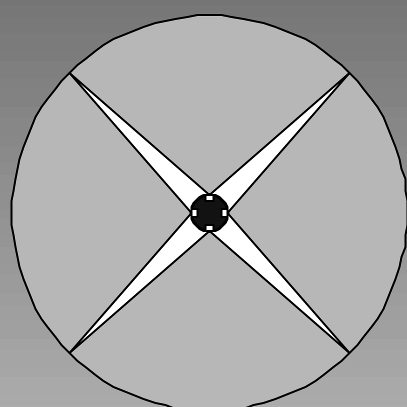
Fixed Fan Beam Transceiver Configuration





Coverage provided by 4 transceivers

- Transmitter
  - Pulsed Microlaser
  - Beam spreading optic
  - Prism window
  - 50° forward looking cone
  - 90° roll coverage
- Receiver
  - Prism window
  - Cylindrical lenses
  - Bandpass filters
  - Focusing lenses
  - Avalanche Silicon APDs
  - Transimpedance pre-amplifiers

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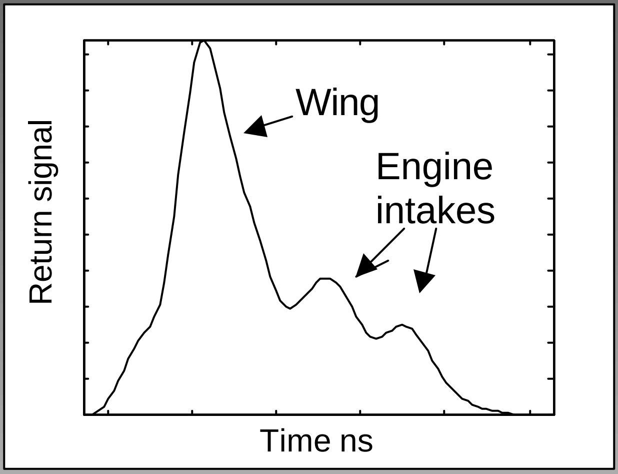
Fixed Fan Beam Sensor - Predicted Performance

- Full 360° roll coverage from four 90° sectors
- Enhanced detection range (compared to existing semiconductor laser sensors)
- Potential exploitation of digitised receiver pulse shape
  - Waveform is sum of pulse reflections from illuminated target regions
  - Down-beam target extent results in pulse extension
  - Target feature extraction
    - Separated target features can result in distinctly identifiable pulse returns
    - Potential for more intelligent trigger point processing
  - Enhanced clutter (cloud) discrimination
    - Distributed scattering media result in significantly extended pulse returns



Typical target pulse signature

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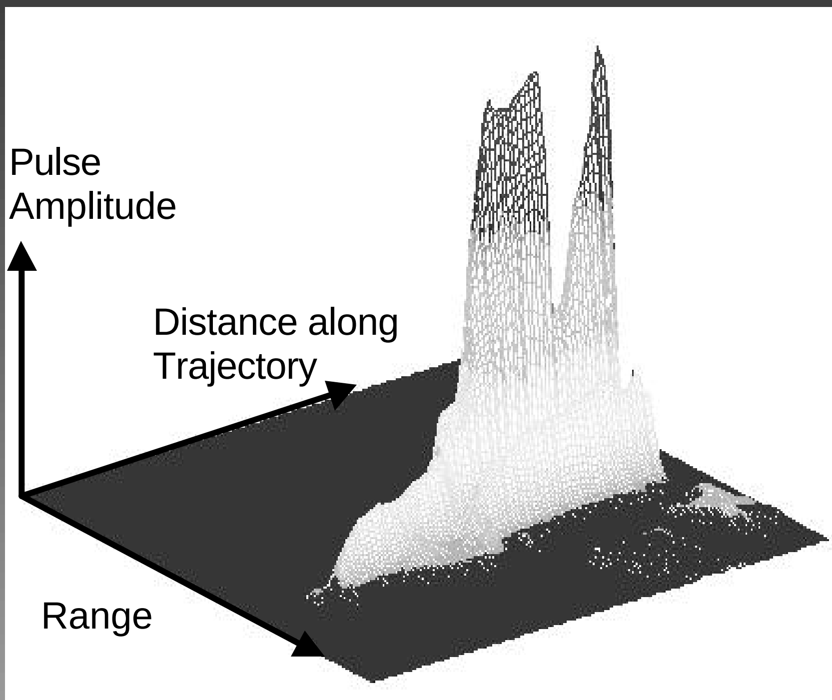
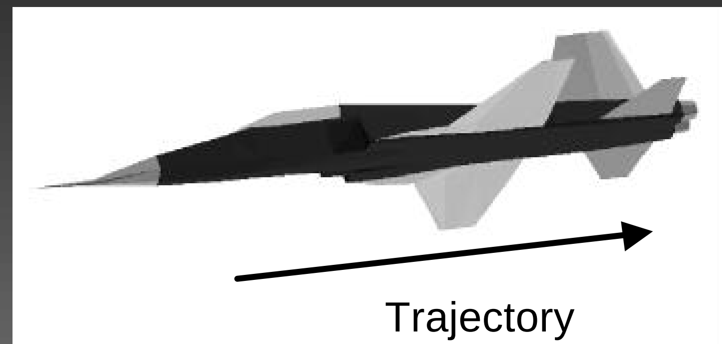
Fixed Fan Beam Sensor - Aircraft Detection in Clear Air



Received waveform sequence



- Target engagement simulation model
  - Received waveforms predicted
  - Plots of sequential waveforms
- Distinct target features evident
  - Nose / fuselage
  - Main wing
  - Tail wing
  - Engines / air intakes

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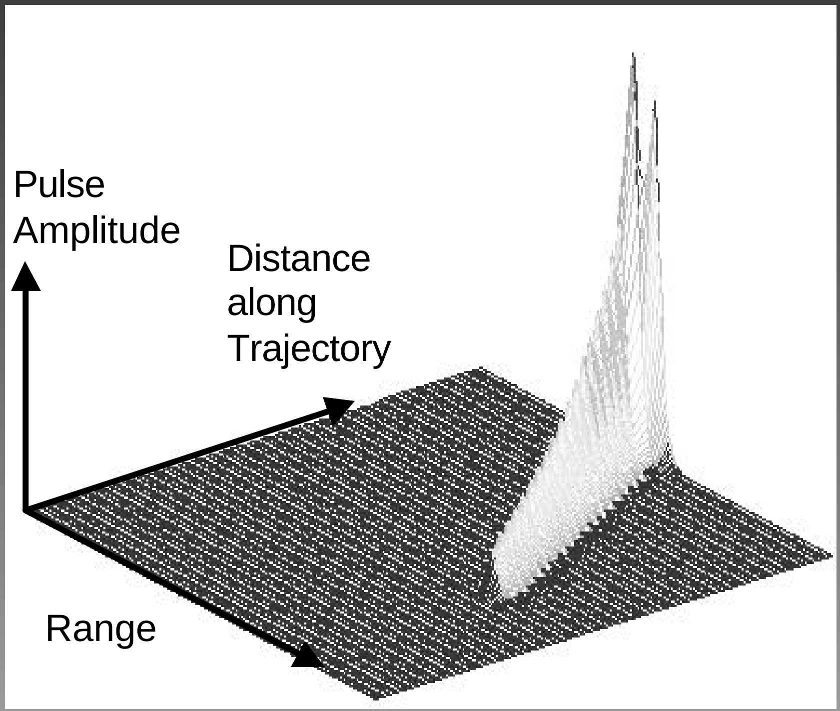
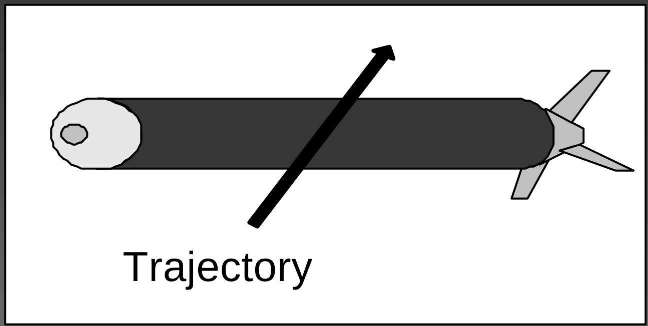
Fixed Fan Beam Sensor - Missile Detection in Clear Air



Received waveform sequence



- Crossing engagement
- 45° off head on
- Down-beam range extent small compared to aircraft case
- Range variation during engagement evident

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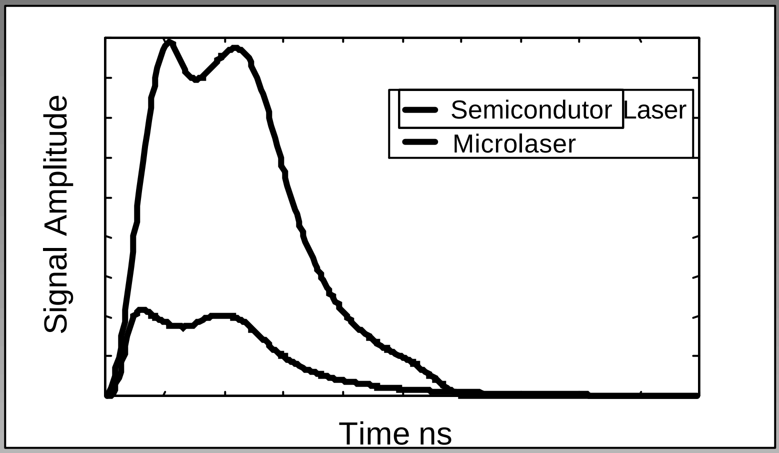
Fixed Fan Beam Sensor Cloud Backscatter Discrimination - Simple Threshold

- Important to prevent false alarm when entering and immersed in cloud
- An amplitude detection threshold offers a simple means of discrimination
  - Threshold set above maximum backscatter envelope
  - Places a constraint on maximum sensitivity and detection range
- Backscatter pulse amplitude and shape is dependent upon:
  - Cloud density (extinction coefficient, ♌, is a useful measure)
  - Particle size distribution (Scattering Function, F(❑), is useful measure)
  - Fuze sensitivity versus range
  - Transmitted pulse width
- Narrower Microlaser pulse width gives reduced backscatter amplitude
  - Improved discrimination



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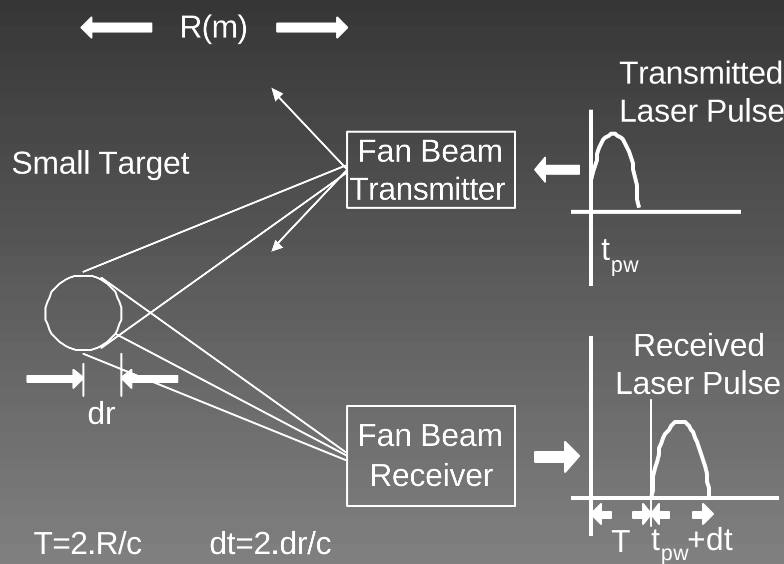
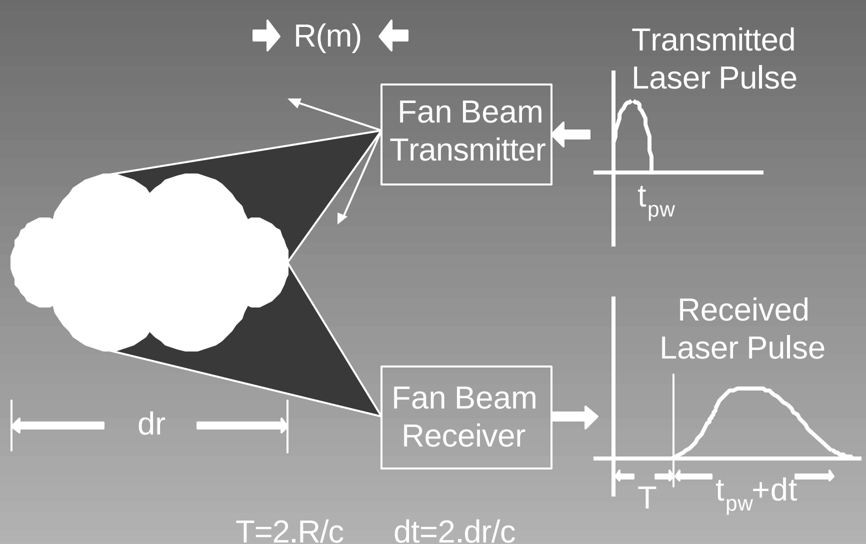
Fixed Fan Beam Sensor Cloud Backscatter Discrimination - Pulse Shape

- Valid target is localised in range
- Reflected pulse exhibits minimal temporal extension





- Scattering sites distributed in range
- Backscattered pulse exhibits significant temporal extension
- Can discriminate on the basis of pulse shape

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Cloud Discrimination - Algorithm Development

- Algorithm evolved [under a UK DERA contract] that incorporates
  - Pulse shape analysis of consecutive received waveforms
  - Each waveform classified as cloud, target, or cloud+target
  - Analysis of (recent) pulse shape history
  - Logic to combine the four sector outputs
- Performance successfully demonstrated by simulating cloud interaction
  - Homogenous cloud conditions
  - Entering & leaving homogenous cloud
    - Planar boundary
    - Various edge depths (distance of transition from clear air)
- Requirement for a more realistic cloud model recognised
  - Spatial density variations representative of real cloud
  - Resolution comparable with sensor range resolution (i.e. ~0.25m)

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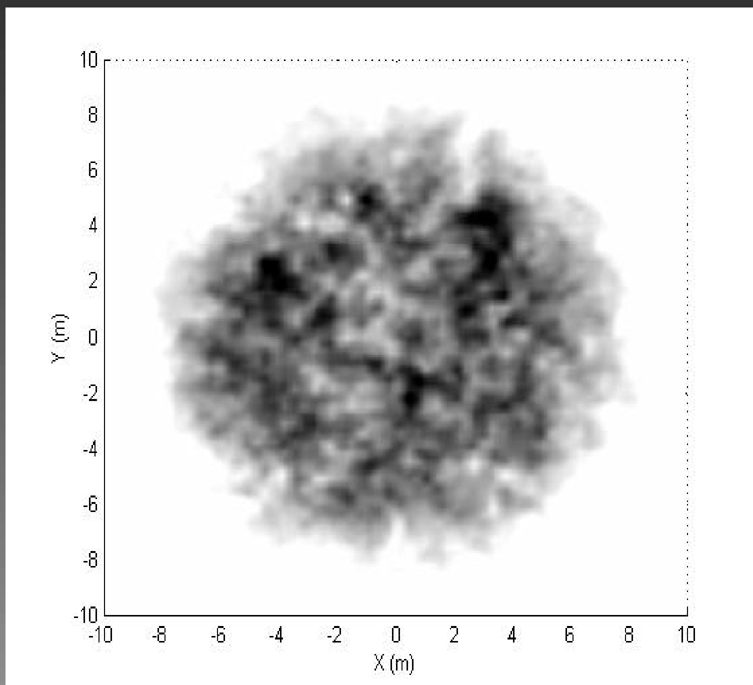
High Resolution Fractal Cloud Model



Grey scale of extinction coefficient

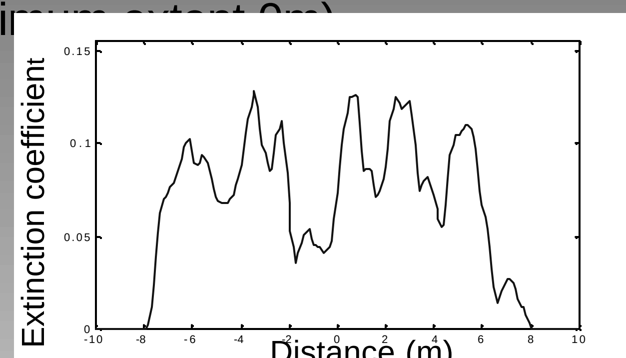
2-D slice through centre

- Fractal based model developed [jointly funded contract with the UK DERA]
- 3-D lattice of extinction coefficient (♌)
- F(❑) assumed uniform
- Fractal techniques employed to generate ♌ lattice values
- Randomly seeded
- Defined minimum and maximum ♌ limits
- Linear gradient applied at boundary (minimum extent 0m)

Typical

1-D ♌

Variation



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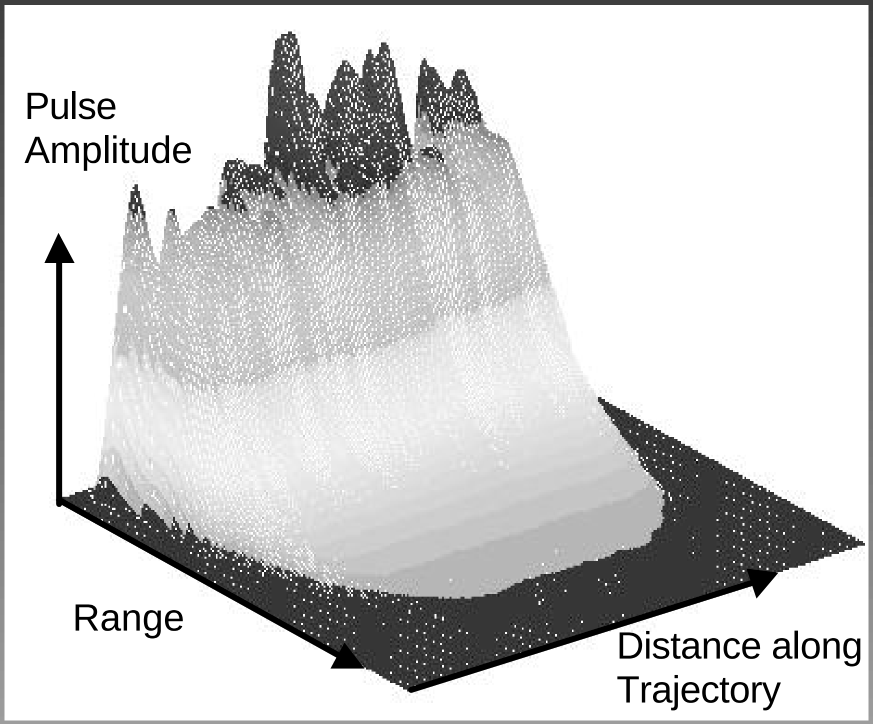
Fixed Fan Beam Sensor - Single Sector Cloud Interaction



Received waveform sequence

- Received backscattered pulse shape evolution
- Trajectory through centre of cloud
- Single 90° fan beam sector
- Significant pulse amplitude and shape variation through cloud
- Most backscattered pulses exhibit temporal extension
  - Some at boundary do not
  - Data from all 4 sectors used by algorithm
- Trajectories through all regions of cloud simulated
- Discrimination algorithm demonstrated not to false alarm

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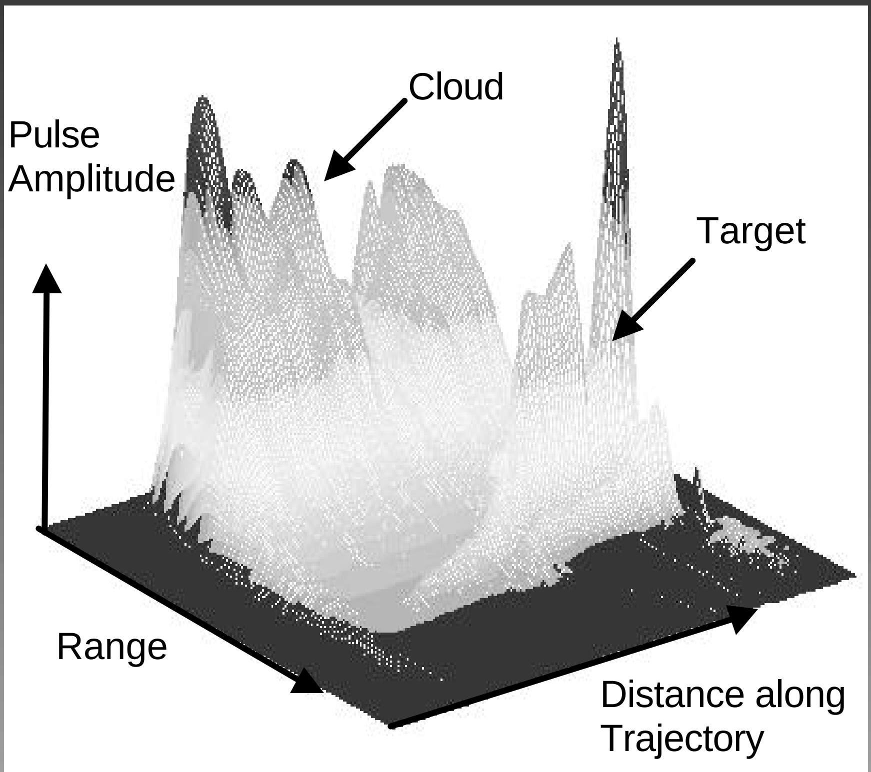
Fixed Fan Beam Sensor - Aircraft Target in Cloud



Received waveform sequence

- Received pulse shape combination of
  - Cloud backscatter
  - Target reflections
- Target located in centre of cloud
  - Near head on engagement
- Single 90° fan beam sector
- Algorithm correctly detects presence of target
- Comprehensive set of engagement conditions simulated
- Performance not greatly degraded from that in clear air

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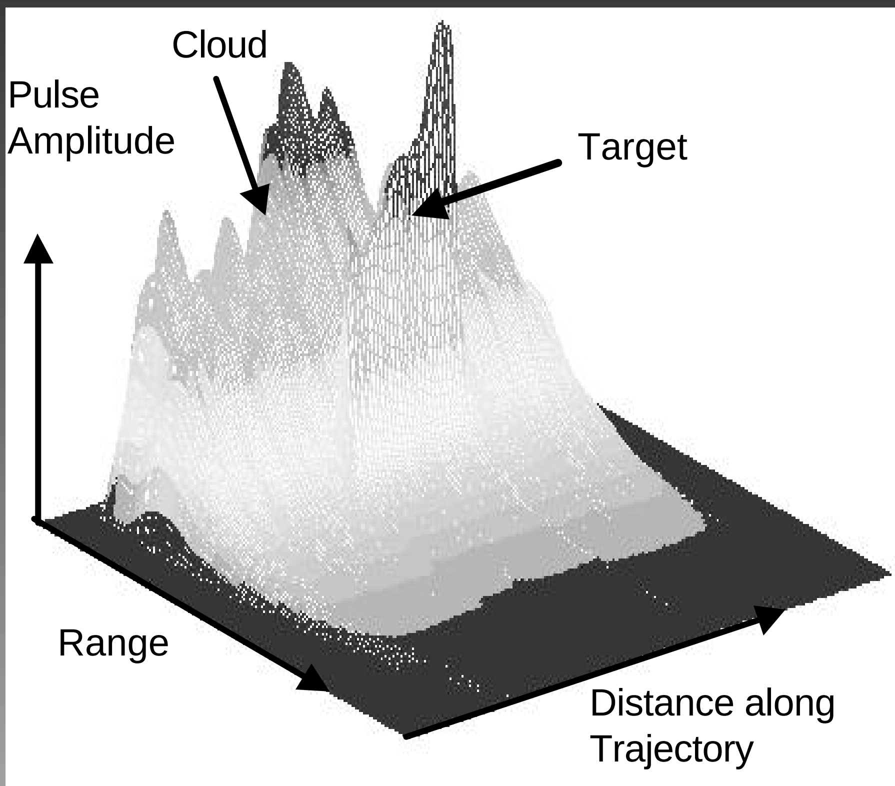
Fixed Fan Beam Sensor - Missile Target in Cloud



Received waveform sequence

- Target located in centre of cloud
  - Near head on engagement
- Single 90° fan beam sector
- Algorithm correctly detects presence of target
- Comprehensive set of engagement conditions simulated
- Performance not greatly degraded from that in clear air

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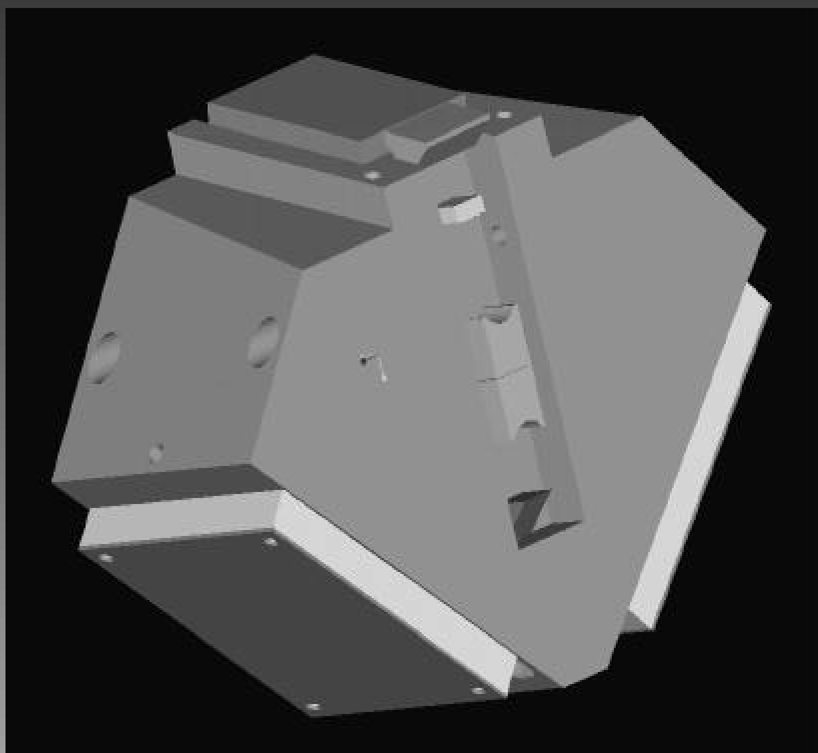
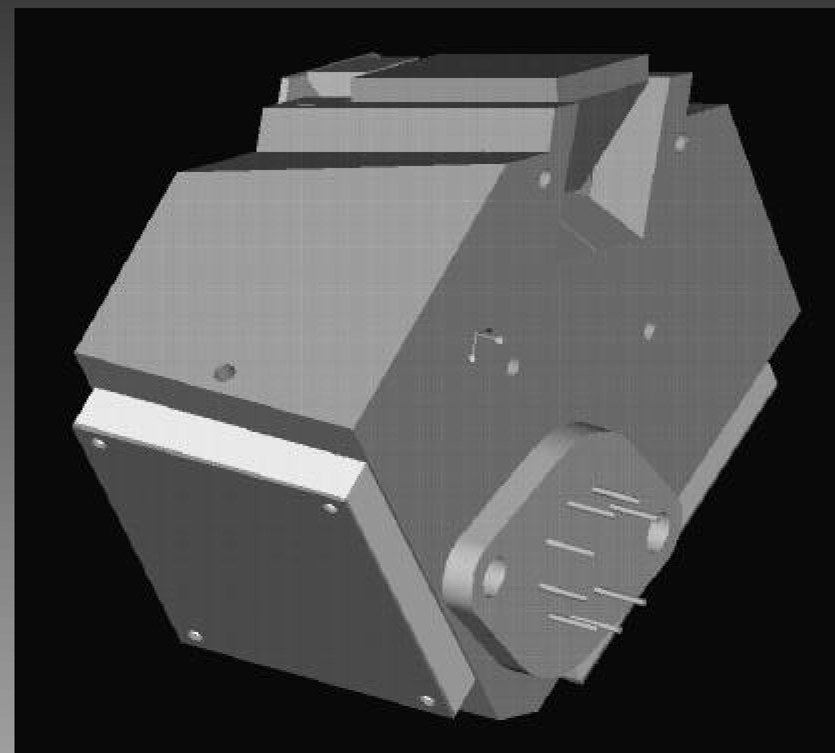
Fixed Fan Beam Transceiver - Initial Packaging Study



View of transmit optics



View showing rear of laser package

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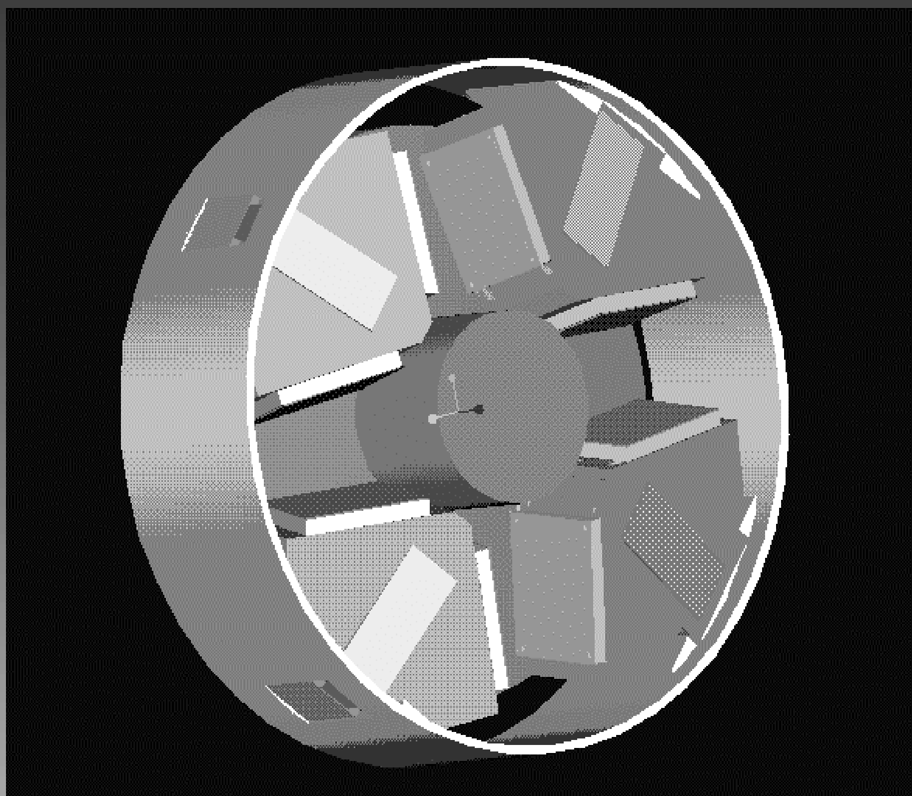
Fixed Fan Beam Fuze - Initial Packaging Study



- Four sector configuration
- Transceivers attach to inside of missile body
- Transceiver windows emerge through cut-outs in missile body
- Central electronics unit
  - Signal processing
  - Power conditioning
- Overall dimensions comparable with existing proximity fuzes

Advanced Laser Proximity Fuzing

Conclusion

- Use of Microlaser technology will provide significant sensitivity and coverage improvements
- Received waveform pulse shape processing algorithms will provide near clear air performance when in cloud
- Hardware Demonstrator (complete mid 2000) will provide practical verification of performance
  - Detection performance tests planned
  - Potential for future target engagement & cloud trials
- Compact packaging concept established
- Enabling technology for Fuze Guidance Interaction [Guidance Aided Fuzing]
  - Scanned pencil beam offers enhanced roll resolution
- Maturity of technology compatible with next generation fuze development